EXOBIOLOGY AND THE SEARCH FOR BIOLOGICAL SIGNATURES ON MARS;

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In preparation for a Mars Rover/Sample return mission we must identify the mission goals and objectives. One of the most important objectives must address exobiology and the question of the possibility of the origin and evolution of life on Mars. In particular, we must define key signatures or bio-markers of a possible extinct Martian biota. To that end we must also identify geographic locations (sites) that are likely to contain traces of past life.

The similarity of the early environments of Earth and Mars, and the biological evolution that we know occurred on early Earth, provide the motivation to seriously consider the possibility of a primordial Martian biosphere. Four billion years ago the surface of Mars could have been conducive to the origin of life.

Terrestrial biological systems are dependent upon the presence of liquid water. Consequently, we must narrow our search for traces of an extinct biota to areas that once were overlain with liquid water (*e.g.,* Valles Marineris). How do we detect traces of this possible extinct life? Initially this search should be based upon, and make use of, the techniques developed in understanding Earth's earliest biological evolution (1). These techniques include identifying key chemical, isotopic, and morphological signatures of life that can be determined on Mars and that can act as key indicators, or signatures, of extinct life. Because the histories of Earth and Mars differ, and because our understanding of the history of Mars has many uncertainties, no single technique will adequately determine if a Martian biota ever existed.

Understanding the geochemical cycling of the biogenic elements (C, H, N, O, P, S) and their compounds (*e.g.* CO_2, H_2O, NO_x) on early Mars, as recorded in the Martian sediment, would provide a useful tool in understanding biological evolution. Isotopic signatures are used to understand early Earth and to analyse the interaction between biological and abiological chemical cycles (2,3). Tracking isotopic changes through the Earth's fossil record seems to be correlated to major changes in the atmosphere and biogeochemical cycling. Banin and Navrot (4) suggested that fixed nitrogen and organic carbon are key elements that are enriched through biological processes above their natural geochemical abundances. Therefore, they may be indicators of biological activity in possible Martian sediment.

We have begun defining sites and experiments in support of a Mars rover sample return mission. Although early Mars and early Earth were very similar there were some differences. One of the most crucial of these was the low pN_2. Nitrogen is an essential element of biological systems. However, N_2 is unusable to life as we know it. It must be transformed into biologically available forms such as NH_4^+, or NO_3^-. Only certain prokaryotic organisms have the capability of transforming N_2 to NH_4^+, (nitrogen fixation). We conducted experiments using extant nitrogen fixing organisms (*e.g., Beijerinckia, Azomonas, Azotobacter, Clostridium, Bacillus,* cyanobacteria), and have shown that at the low pN_2 of early Mars (18 mb), these organisms are able to fix nitrogen (*e.g.,* Figure 1). Thus, the low pN_2 of early Mars would not have prevented the evolution of a biological nitrogen fixing system as we know it.

In addition, analyses based on computer models of abiotic processes of CO_2 loss from Mars suggest that the CO_2 from the atmosphere may have precipitated as carbonates and be buried within the Martian regolith. We are currently investigating the carbon cycle of perennially frozen lakes in the dry valley of Antarctica. These lakes have been purported to be a model system for the ancient Martian lakes. By understanding the dynamic balance between the abiotic *vs.* biotic cycling of carbon within this system, we are gathering information that will enable us to interpret data obtained by a Mars rover with respect to possible carbonate deposits and the processing of carbon by biological systems. These ancient carbonate deposits, and other sedimentary units would contain traces of biological signatures that would hold the key to understanding the origin and evolution of life on Mars, as well as on Earth.

REFERENCES

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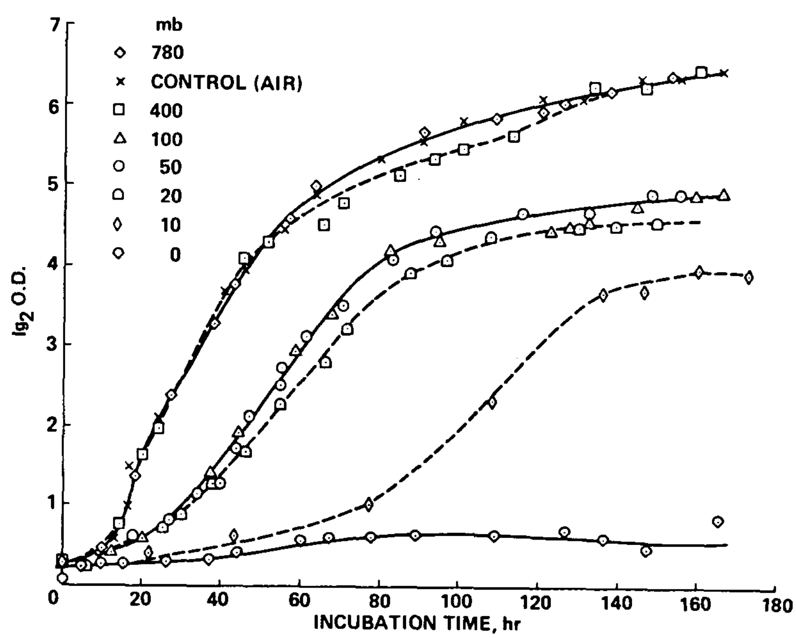

Figure 1. Growth of *Azotobacter vinelandii* under various partial pressures of dinitrogen in a nitrogen free medium. Growth was measured turbidimetrically with a Klett-Summerson Colorimeter using a red (#66) filter.